Application No.: 10/716,181
Inventor(s); James P. Nadeau, Pei Zou and Jason H. Arjavac
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Amendments to the Specification:

Please add the following to the specification:

METHOD AND APPARATUS FOR CONTROLLING ~~TOPOLOGICAL~~TOPOGRAPHICAL VARIATION ON A MILLED CROSS-SECTION OF A STRUCTURE

[1000] The present invention relates to charged particle beam milling and, in particular, to a method of controlling ~~topological~~topographical variation on a cross-section of a structure.

[1019] Thus, there is still a need for an improved method of controlling ~~topological~~topographical variations when milling a cross-section of a structure such as a write head pole. A reduction in ~~topological~~topographical variation will produce a more planar cross-section face and accordingly can improve the accuracy of metrology applications such as measuring a width of the cross-section of such a structure.

[1020] It is an object of the invention, therefore, is to allow improved control over ~~topological~~topographical variations when milling a cross-section of a structure, such as reducing ~~topological~~topographical variation on a cross-section of a write-head in order to improve the accuracy of metrology applications. A preferred embodiment of the invention described and claimed herein comprises the use of a protective layer deposited over the structure, followed by ion milling to expose the cross-section of the structure, and SEM metrology to determine dimensions such as the width of the structure. In a preferred embodiment of the invention, ~~topological~~topographical variation is reduced by using a protective layer which comprises a material having mill rates at higher incidence angles (up to 90 degrees) that closely approximates the mill rates of the structure at those higher incidence angles. In another preferred embodiment of the invention, a protective layer of carbon is deposited over a structure composed of

Permalloy to allow for improved metrology of the Permalloy structure. In still another preferred embodiment of the invention, ~~topological~~topographical variation can be intentionally introduced by using a protective layer that comprises a material having mill rates at higher incidence angles that do not closely approximate the mill rates of the structure at those higher incidence angles.

[1031] Preferred embodiments of the present invention are directed to methods and an apparatus for controlling topographic features or variations on a milled cross-section of a structure. The topographic features that can result from milling the cross-section can be reduced or even eliminated by careful matching of the substrate (the material that the feature is composed of) with a protective overcoat material. Specifically, an appropriate overcoat material according to the invention will have a mill rate at higher incidence angles (up to 90 degrees) that closely approximates the mill rate of the substrate material at those higher incidence anglesat which the milling cross section is formed. Preferred embodiments of the present invention can thus be used to produce a cross-section face that is almost perfectly planar. This allows for SEM metrology based entirely upon material differences rather than variations in topography, which is desirable for metrology on a structure. In contrast, ~~topological~~topographical variations can be intentionally introduced by choosing an overcoat material having a dissimilar mill rate at higher incidence angles than the mill rate of the substrate at those higher incidence angles.

[1048] This recess, along with the curtaining effect it causes, is a ~~topological~~topographical artifact associated with the selection of the overcoat material (tungsten) and the process of producing the cross section. ~~Topological~~Topographical variations, resulting both from the recess and the collection of sputtered material, introduce gray level variations in the image that compete with the more relevant contrast mechanism based on material

differences. These gray level variations can make edge recognition difficult and can possibly lead to a less accurate cross-section measurement by automated metrology software.

[1050] By matching the mill rate of the overcoat material and the underlying structures, ~~topological~~topographical variations resulting from milling the cross-section are minimized to a point where they will not affect the metrology. The resulting measurements are more precise and more robust to process variations. Typically, the closer the milling rates can be matched at the higher incidence angles which actually form the cross-section face, the more ~~topological~~topographical variations resulting from the milling process will be reduced.

[1051] For a typical milling process, the cross-section face will be formed at incidence angles from around 75 degrees up to 90 degrees. As a result, matching the mill rates for this range of incidence angles is preferred. However, skilled persons will recognize that variations in milling conditions, for example variation in mill pattern or ion beam dose, can sometimes result in a cross-section forming at a different incidence angle. Applicants believe that matching milling rates through a larger range of high incidence angles (from around 45 degrees up to 90 degrees) would allow ~~topological~~topographical variations to be controlled for a much wider range of milling conditions. Due to the limited number of available overcoat materials, however, it may not always be possible to match mill rates through a larger range of higher incidence angles. For most metrology applications using typical milling conditions, it will be preferable to match mill rates at incidence angles higher than 75 degrees. In most cases, this will not only allow for a significant reduction in ~~topological~~topographical variation over the prior art, but will also result in a number of acceptable overcoat materials—which in turn will allow factors such as electron emission contrast (discussed below) or ease of overcoat application to be taken into consideration.

[1061] According to the present invention, the same general steps can be followed to determine the width of a structure composed of a material other than Permalloy provided that an appropriate overcoat material is substituted for the carbon layer. Applicants have discovered that matching the milling rate of the protective layer and the structure being measured at higher incidence angles (greater than 75 degrees up to an angle approaching 90 degrees) reduces curtaining. Where the protective coating mills at about the same rate as the structure, ~~topological~~topographical artifacts that can collect redeposited particles are minimized. The lack of ~~topological~~ topographical variation in the milled cross section results in a more defined edge between the two materials and, as a result, more accurate determination of the structure's width by an SEM and automated metrology software.

[1063] FIG. 7 is a flowchart showing the steps of selecting a suitable overcoat material in order to control ~~topological~~topographical variation in a milled cross-section according to a preferred embodiment of the present invention.

[1065] In step 704, a preliminary group of acceptable overcoat materials is identified by using reference values for mill rates throughout the desired range of incidence angles. As discussed above, in order to reduce ~~topological~~topographical variation, an appropriate overcoat material will have mill rate throughout the desired range of incidence angles that closely approximates the mill rate of the structure material over that same range of incidence angles.